

# PHYLOGENETIC POSITION OF THE BACTERIA<sup>1</sup>

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The subject of the phylogenetic position of the bacteria has been approached by many students. Early workers came to no more diverse conclusions than do modern ones. Some investigators, for example NÄGELI (24) and GÖTSCHLICH (14), have placed the bacteria with the fungi, while COHN (9), MIGULA (22), and SACHS (26) placed them with the algae. The early workers who assigned the bacteria to the fungi did so because both fungi and bacteria lack chlorophyll, and may thus be regarded as similarly degenerate algae, and because there are genera such as *Corynebacterium*, *Actinomyces*, *Streptothrix*, and *Oidium*, that may well be regarded as transitional forms. Classifiers of the fungi have not sufficiently emphasized the fact that in a group where chlorophyll is absent there is no compelling reason for presuming that the simpler forms, the bacteria, were descended from the higher ones, as the workers thought who considered them as directly descended from the algae. Even DE BARY (1), although he uses NÄGELI'S name "Schizomycetes" (fission fungi) for the bacteria, insists that they are not fungi, nor closely related to or descended from fungi.

The reason for classing the bacteria as a subordinate group of the algae has usually been the exceedingly close morphological resemblance of the higher bacteria to the blue-green algae (Cyanophyceae or Myxophyceae). COHN was the first to emphasize the relationship between these groups. The Cyanophyceae were long thought to be the most simple autotrophic forms. More modern systematists have separated the blue-green algae from those with sexual reproduction, and have united them with the bacteria. Thus ENGLER (12), in his second phylum Schizophyta, included only the two classes Schizomycetes and Schizophyceae; WARMING (28) made a similar division of his class Schizophyta; while BESSEY (3) in his phylum Myxophyceae, class Archiplastideae

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(blue-green algae without nuclear membrane), placed the Bacteriales as an order coordinate with two orders of the blue-green algae. BÜTSCHLI (6) and KLEBS (19) emphasized the common characters of the bacteria and the protozoa.

Today the question is apparently no nearer a solution than it was forty years ago. The various views are based on the consideration of different life manifestations. Close relationship between bacteria and protozoa, however, is no longer emphasized. The principal views held today are three: (1) that the bacteria are members of the group of fungi, (2) that they are derived from or closely related to the Cyanophyceae, and (3) that they are the primitive forms from which fungi and algae are derived. The first two opinions are held by morphologists. Those who have regarded the manner of division and sporulation, the external characters of the organism so to speak, and those who hold that bacteria possess a small oval or round nucleus, have allied the bacteria with the fungi. Others who have studied their nuclear structure have allied them with the Cyanophyceae. Chemists and general students of evolution have recently considered them as ancestors of the other groups.

The morphological field has been reviewed carefully by MEYER (21), who holds that the closest affinities of the bacteria are with the fungi. The bacterial nucleus, according to his conception, is similar to the nucleus of the fungi. SWELLENGREBEL (27), GARDNER (13), and DOBELL (11) have observed structures, which they believe to be nuclei, that have marked resemblance to the chromophyll portion of the central bodies of the Cyanophyceae. GUILLIERMOND (15) and a number of other workers hold the bacterial nucleus to be "chromidial" or finely distributed in the cytoplasm. DOBELL finds structures resembling all these types, which he holds to be nuclei, and he believes the bacteria to be related most closely to the Cyanophyceae. WEST (29) described a blue-green alga, *Myxobactron*, which shows no differentiation of its protoplasm. PARAVICINI (25) has recently described minute compact structures that he believes to be nuclei.

JENSEN (18) rearranged the bacteria on a chemical basis, and defined their relation to the algae, fungi, and protozoa, presuming



that the earth was dark when life began, and that chlorophyll-free bacteria, probably those capable of oxidizing methane, were the earliest forms of life with which we are familiar today. JENSEN derived the blue-green algae from the sulphur bacteria, the fungi from the oxidizing bacteria by way of the Actinomycetes, and the higher bacteria from the earliest nitrogen-reducing organisms. KLIGLER (20) was also of the opinion that bacteria may well have been the earliest forms of life, and he placed the methane-oxidizing type at the base of his tree. BREED, CONN, and BAKER (4) pointed out that there is no proof that the world was dark when life began; that in case it was light the ancestors of the blue-green algae or of the phototrophic pigment bacteria, which use sunlight to metabolize organic substances, may have been the most primitive forms; or that the most primitive form may be entirely unknown to us. Thus we see that because of the discovery of the existence of autotrophic bacteria the old question of the origin of the bacterial group is again open.

When the synthesis of inorganic substances into organic material was thought to be possible only by the aid of chlorophyll, the natural trend of evolutionary reasoning led to the derivation of other forms of life from simple chlorophyll-containing ones. Bacteria apparently are simpler than the most simple chlorophyll-bearing algae. They were therefore thought to be degenerate. Workers who saw in them affinities with the chlorophyll-free fungi were not careful to state what their relationship with the fungi really might have been. The reader is usually left with the impression that they are in an intermediate position or related to the higher fungi. MEYER, who excluded the *Thiobacteria*, *Chlamydobacteria*, and *Myxobacteria* from his Eubacteria or bacteria proper, placed his group as the second class of the Eumycetes next to the Phycomycetes or algal fungi. CLAYPOLE (7) considered both bacteria and fungi to be derived from the leptothrix-tuberculosis group.

A rather suprising paper has recently appeared by BERGSTRAND (2), who has observed the budding and branching of *Corynebacterium* and other forms, and believes that the bacteria are closely related to the fungi. Budding and binary fission are not so different in their nature that they should be considered very important



characters. One genus of yeasts, the *Schizosaccharomyces*, divide as do the bacteria. Apparently typhoid bacilli may either bud or divide by fission HORT (16). Upon this one character of budding, BERGSTRAND lays so much emphasis that he refuses to consider other characters, also morphological, which show similarity between the bacteria and other forms: "To discuss further the eventual relationship of Cyanophyceae to bacteria does not seem necessary, because any such theory would appear false at the moment that it became clear that bacteria are more closely related to fungi, as I shall show." It must be noted that, like MEYER, BERGSTRAND excludes from his bacterial group the higher bacteria which do not resemble the fungi as much as they do the algae. One would be equally justified in naming as bacteria all the chlorophyll-free rods except the branching and budding ones. BERGSTRAND defines the bacteria as Fungi Imperfecti. The Fungi Imperfecti are an entirely artificial group comprising fungi that have not developed sexual characters, those that have lost such characters, and those that have not been studied sufficiently to determine their true relationships. BERGSTRAND concludes that bacteria are to be regarded as Fungi Imperfecti that have developed through the reduction of higher forms, and not as lowly primordial organisms to be placed at the very beginning of the organic world. An example of his logic is as follows: "Of course if one regards bacteria as Fungi Imperfecti one cannot accept the theory that the chromatin is spread diffusely in the cell body, because this assumes it would seem a much lower developmental stage."

It is not the intention of this paper to criticize workers for connecting bacteria with fungi because of morphologic relationships between the two groups. BERGSTRAND'S observations serve to strengthen the tie between the fungi and the bacteria, but the lightness with which he proposes the degeneracy of the latter forms from the former is a novel process to comparative biological reasoning. The trend of evolution is rarely in the direction of degeneracy. Degeneracy occurs as a consequence of a parasitic habit or because of abundant food supply. It is usually accompanied by vestigial traces of a former complexity. The characters which the bacteria and fungi have in common are not manifestly vestigial in the



bacteria. The supposed loss of sexual characters among the fungi has been attributed to their change from water forms to air forms, but bacteria are not air forms. The theory of the degeneration of the bacteria from the algae was a very peculiar one, imposed by ignorance of certain primitive bacteria. It is now known that bacteria exist which are autotrophic and can secure growth energy from inorganic carbon, so that their lack of chlorophyll is no longer a reason for considering them degenerated from the chlorophyll-containing forms. The existence of autotrophic fungi, to my knowledge, has never been demonstrated.

There is a simple group, therefore, the members of which are autotrophic; and two diverse complex groups, one of which (the fungi) is not autotrophic and may not be homogeneous. Both of these complex groups show marked resemblances to the simple one. JENSEN'S scheme, which derives both of them from the simple one, is not to be lightly thrown aside. It coincides too well with the general scheme of evolution. We may, if we wish, consider the question entirely open, but nomenclature and classification should be so formulated that they do not deliberately mislead the amateur on the subject of these relationships. Formerly the tendency in botanical classification was to make a treelike structure, throwing groups together that had but superficial resemblances, but classifiers today are more prone to refuse to indicate relationships where descent is not fairly certain, and to group the plants in phyla like the zoological phyla, whose connections may or may not be understood.

The bacteria, fungi, and blue-green algae, therefore, may be all in one phylum, or may be placed in three separate phyla, but to place the bacteria with either fungi or Cyanophyceae is inconsistent, because it leaves out of consideration the third group which may be equally related to the bacteria. Probably the trend of classification would favor the separation of these groups into three separate phyla, for to place the fungi and Cyanophyceae together is rather stretching the limits of the botanist's conception of a phylum. Moreover, in view of the existing divergent opinions, a classification that does not commit one on the subject of these relationships is preferable. A name for the phylum that is to



contain the bacteria only should not indicate for them a subordinate position in another group as does the name "Schizomycetes," proposed by NÄGELI (23) in 1857 for a mongrel group which contained bacteria, sporozoa, and oscillaria, a group whose affinities he hesitated to suggest. The connotation of this term has always been "fission fungi," and its German form "Spaltpilze" has been widely used. And yet BUCHANAN (5) finds it entirely appropriate and valid and proceeds to place his Schizomycetes with the Cyano-phyceae. Article 51, division 4, of the Vienna rules (17) considers the name Schizomycetes as invalid. "Everyone should refuse to admit a name . . . when the group which it designates embraces elements altogether incoherent, or when it becomes a permanent source of confusion and error."

We should choose for the bacterial phylum a name that will immediately be understood by the non-professional worker. Names like *Phytozoidia* Perty of course are objectionable. *Vibrio* Ehrenberg probably included certain infusoria as well as bacteria. *Vibrionia* Cohn did not include forms later studied by that author. *Bacteria* Cohn (8) probably included all the forms that we today call bacteria except *Beggiatoa*, and it did not include members of other groups. As the Committee of the Society of American Bacteriologists (10) places 1880 as the date at which considerations of priority are to commence, we are free to choose from among these names. Bacteria implies no relationship to other groups. It is otherwise highly suitable because it is understood by laymen and is short and euphonious. The following was COHN's conception of the group: "Die Bakterien sind chlorophyllose Zellen von kugelig, oblonger oder cylindrischer, mitunter gedrehter oder gekrümmter Gestalt, welche ausschliesslich durch Querteilung sich vermehren, und entweder isoliert oder in Zellfamilien vegetieren."

In consideration of the fact that no relationship of the bacteria to other groups has been generally accepted the following phylum is proposed:

BACTERIA (nov. phyl.).—Simple one-celled plants that multiply typically by binary fission and occasionally by budding. They show no form of sexual multiplication. They rarely contain cellulose and do not contain chlorophyll or phycocyanin.



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